Recommended Practices for CNG Fueling Station Design, Construction and Operation

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NGV Technology Forum

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Available Modules

- CNG 101 - An Introduction to Compressed Natural Gas for use as a Vehicle Fuel
- CNG 201 - CNG Code Reference Guide
- CNG 301 - Advanced CNG Compressor Topics
- CNG Station Design & Sizing
- Comparative Life Cycle Analysis of Gas Engines vs Electric Motors
- CNG Station Filtration
- CNG Fueling Procedures
- CNG Station Safety
- CNG Station Enhancements

CNG 101

An Introduction to Compressed Natural Gas for use as a Vehicle Fuel

Version 1.0

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies

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CNG 201

CNG Code Reference Guide Version 0.2

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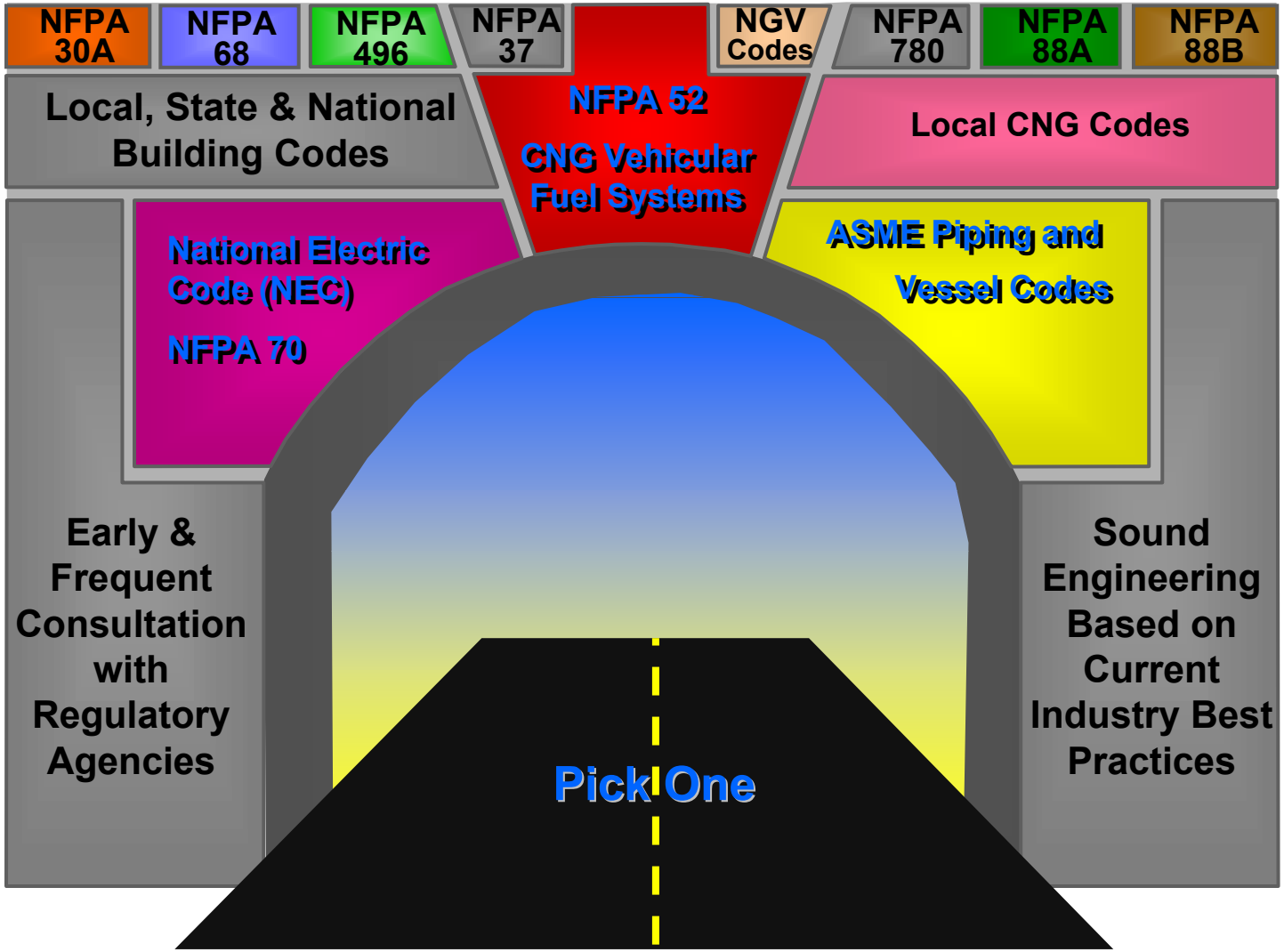
NFPA 30A
NFPA 68
NFPA 496
NFPA 37
NFPA 52
CNG Vehicular Fuel Systems
NGV Codes
NFPA 780
NFPA 88A
NFPA 88B
Local, State & National Building Codes
Local CNG Codes
National Electric Code (NEC)
NFPA 70
ASME Piping and Vessel Codes
Early & Frequent Consultation with Regulatory Agencies
Sound Engineering Based on Current Industry Best Practices
Pick One

CNG Station Sizing & Budgeting Calculator

Best Practice # 3 Version 1.0

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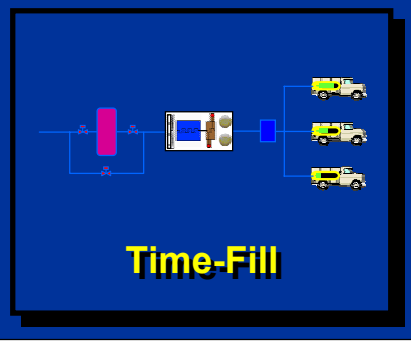
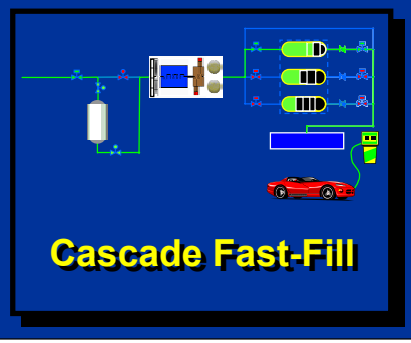
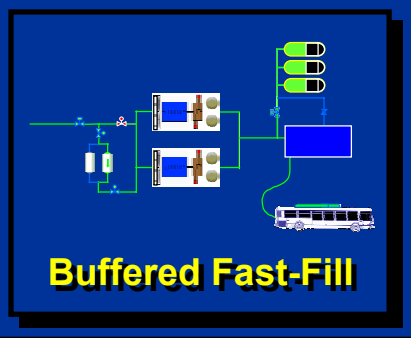
CNG Stations



Time Fill is generally used in situations where vehicles return to the yard for several hours. Small time fill stations may utilize refueling appliances for compression. Larger time fill stations use compressors ranging from 10 hp to several hundred hp. A total fill cycle will usually require 8 or more hours



Cascade Fast Fill is generally used in situations where a number of smaller vehicles (10-30) are filled in a peak fueling period (30-90 minutes), or where large vehicles are fueled sporadically throughout the day.



Buffered Fast Fill is generally used in situations where large vehicles are fueling on a continuous basis. Unlike Cascade systems that primarily fill vehicles from stored gas, the Buffer system provides most of the vehicle fill directly from the compressor(s). The Buffer storage is utilized to allow the compressor(s) to continue to run loaded between vehicle fills.

CNG Station Safety

Best Practice #5 Version 1.0

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CNG 301

Advanced CNG Compressor Topics

Version 1.0

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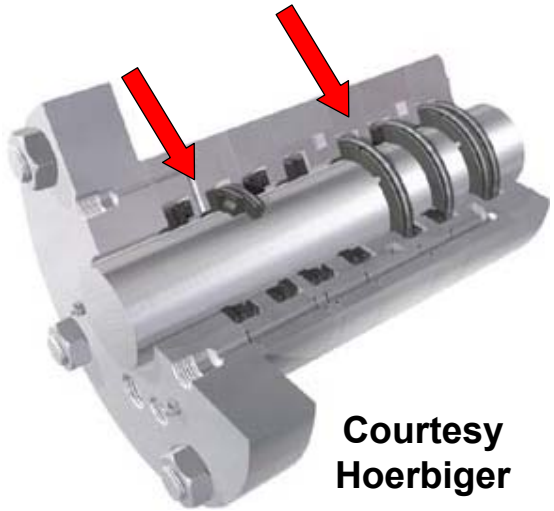
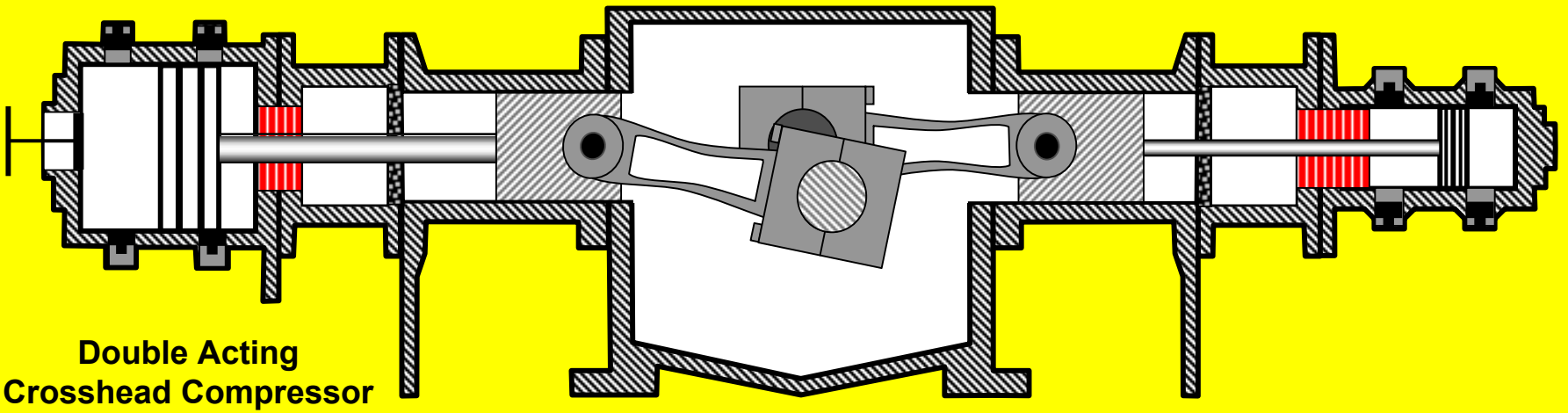
Compressor Components

Seals or Packings

Seals or packings are installed around the piston rod to provide a seal between the cylinder and atmosphere. The seals are energized with a garter spring. Higher pressure stages require more seals. The seal carrier assembly may be liquid cooled and/or lubricated on some machines.



Courtesy
Hoerbiger



Double Acting
Crosshead Compressor

Rod Load

Rod load is defined as the net force acting on the piston rod. This force limits the size and operating pressure allowed for a given cylinder. Excessive rod load could cause premature failure of the wrist pin or bearings, or in extreme cases catastrophic failure of the piston rod, crosshead, connecting rod, crankshaft or other compressor components.

Rod load consists of a number of components. The major factor affecting rod load is the pressure due to compression applied to the piston face and back. Other factors including inertial loads contribute to the total rod load but will be ignored in this example as they are generally minor in their effect.

Simple Example:

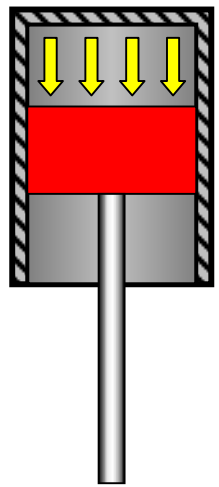
Discharge pressure = 600 psig

Piston Diameter = 4”

Rod load = discharge pressure x piston area

= 600 psig x (pi x $(4/2)^2$)

= 7540 lbs force



Compressor Simulation

Flow Conditions & Horsepower

Most simulation programs state compressor flow in Million Standard Cubic Feet Per Day (MMSCFD). Note that there is a 3-5 % tolerance on performance data.

From		To
0 MMSCFD	=	0 SCFM
0 SCFM	=	0 MMSCFD

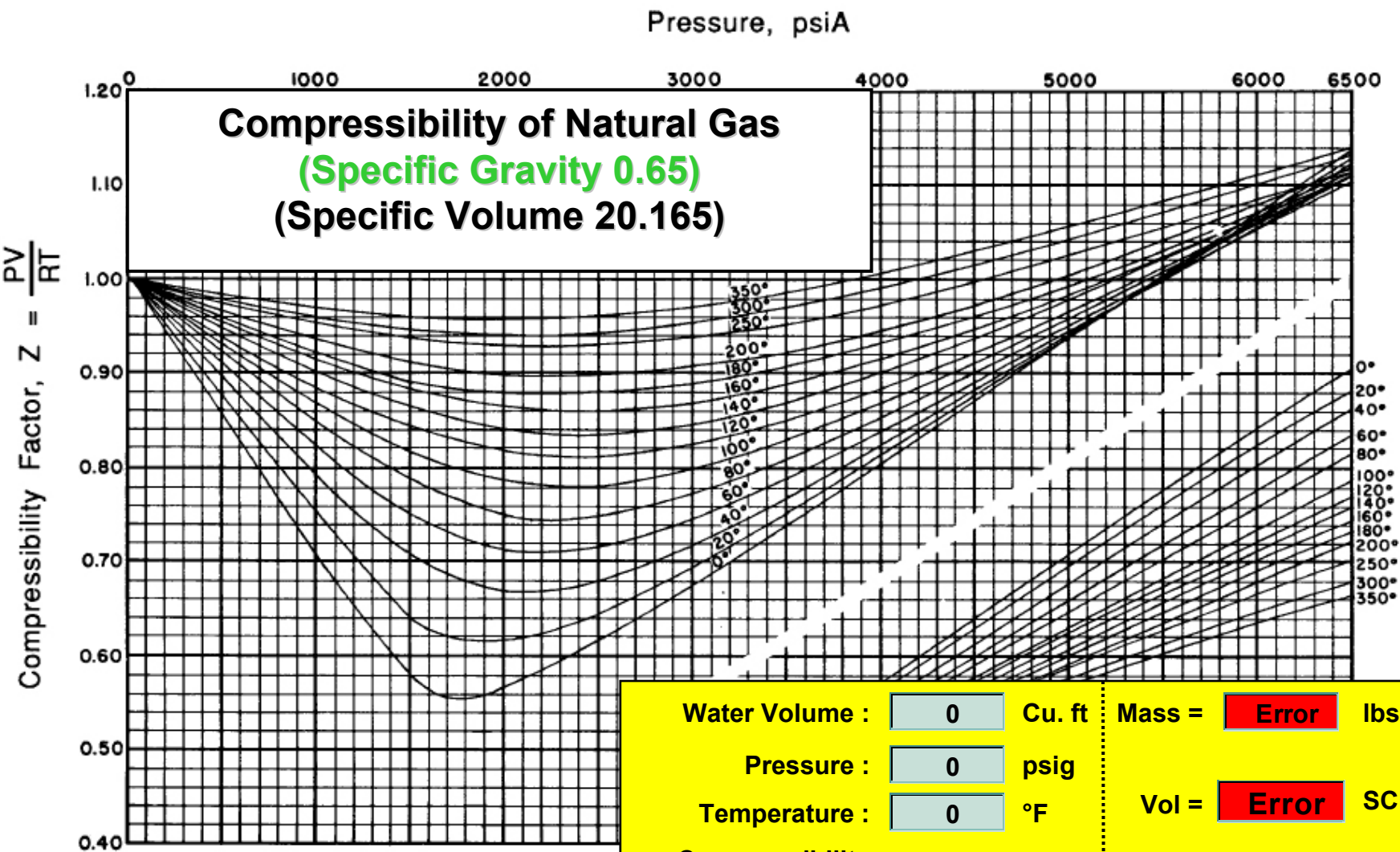
Macros must be enabled!

Courtesy
GE Gemini

```
ELEVATION(FT):0        ATMOS. PR.(PSIA):14.700     AMB.TEMP(DEG F):100
Tc(DEG R):358.2        Pc(PSIA):672.5       PISTON SPEED (FPM): 900
DRIVER: Caterpillar      COMPRESSOR: GEMINI          STROKE (IN): 3.000
MODEL: G3408TA           MODEL: H304                 ROD DIA (IN): 1.125
MAX BHP: 400             MAX BHP: 400.0              R/L TENSION: 10000
MAX RPM: 1800            MAX RPM: 1800               R/L COMPR.: 10000
DRIVER LOAD(%): 92.3     DESIGN RPM: 1800            R/L COMB.: 20000
----------------------------CYLINDER DATA-----------------------------
CYLINDER #.........   1       2       3       4       5       6
STAGE #............   1       1       2       2       3       3
CYL. BORE.......(IN)  3.500   3.500   3.000   3.000   1.500   1.500
M.A.W.P. .....(PSIG)  1250    1250    3500    3500    6000    6000
CYL. ACTION .(DA/SA)  DA      DA      SACE    SACE    SAHE    SAHE
PISTON DISPL...(CFM)  57.0    57.0    19.0    19.0    5.5     5.5
---------------------PRESSURES AND TEMPERATURES----------------------
INLET PRES....(PSIG)  271.0   271.0   850.6   850.6   2179.8  2179.8
DISCH. PRES...(PSIG)  876.3   876.3   2246.0  2246.0  4500.0  4500.0
COMP. RATIO .(Pd/Ps)  3.150           2.612           2.077
Ts...........(DEG-F)  60      60      120     120     120     120
Td (ADIAB)...(DEG-F)  198     198     247     247     214     214
Td (INTERNAL)(DEG-F)  NVD     NVD     NVD     NVD     NVD     NVD
-------------------FLOW CONDITIONS AND HORSEPOWER--------------------
CAP.PER CYL.(MMSCFD)  1.10    1.10    1.10    1.10    1.10    1.10
STAGE CAP...(MMSCFD)  2.21            2.21            2.21
SP. GRAVITY..(Air=1)  .599    .599    .599    .599    .599    .599
K VALUE .....(Cp/Cv)  1.260   1.260   1.260   1.260   1.260   1.260
ZS.................   .955    .955    .914    .914    .850    .850
ZD.................   .948    .948    .945    .945    1.000   1.000
CYL. IHP ..(PER/CYL)  68      68      61      61      41      41
CYL. BHP ....(TOTAL)  350
TOTAL UNIT BHP .....  350 + 20(AUX. HP) = 370
----------------------------CLEARANCE DATA----------------------------
C.E. VOL. EFF....(%)  66.88   66.88   70.08   70.08   .00     .00
-----------------------ROD LOADS AND REVERSALS-----------------------
VLV.VEL. INLET.(FPM)  5165    5165    7700    7700    6915    6915
VLV.VEL. DISCH.(FPM)  5165    5165    7700    7700    6915    6915
ROD LOAD TENS...(LB)  4965    4965    5282    5282    5282    5282
ROD LOAD COMPR..(LB)  6131    6131    7374    7374    7374    7374
```

The simulation program will compute a specific gravity (usually between .55 & .65) based on input gas composition. The simulation program calculates the compressibility factor Z at suction and discharge conditions to each stage.

Compressibility of Natural Gas – Calculator



Water Volume :	0	Cu. ft	Mass =	Error	lbs
Pressure :	0	psig			
Temperature :	0	°F	Vol =	Error	SCF
Compressibility Factor (Z): (Read from Graph)	???				

CNG Fueling

Procedures & Demonstrations
Best Practice #4 Version 1.0

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Temperature Compensation Calculator

3000 psi @ 70 F (Nominal Fill Pressure)

Enter Gas Temperature:	70	ºF
Calculated Fill Pressure:	3000	psi

Code prohibits fueling beyond 3750 psi regardless of temperature.

3600 psi @ 70 F (Nominal Fill Pressure)

Enter Gas Temperature:	70	ºF
Calculated Fill Pressure:	3600	psi

Code prohibits fueling beyond 4500 psi regardless of temperature.

The temperatures entered above represent the gas temperature inside the vehicle cylinder.

Fire or Emergency Procedure

- Activate fire pull and/or ESD button.
- Evacuate the area.
- Call emergency phone numbers (911 or other).
- Notify supervisor.

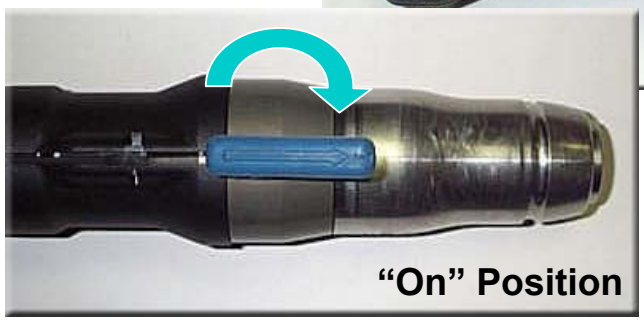
Qualified personnel may isolate all natural gas in the area and attempt to extinguish the fire.

Fast Fill Nozzles - Staubli

When the handle is rotated 180º to the "on" position, an arrow visible from the top, points toward vehicle. Click here for video.

Staubli 3000 psi (Off)

Staubli 3000 psi (On)



"On" Position

Qualitative & Quantitative Analysis of Gas Engines & Electric Motors

As Prime Movers on CNG Compressors

Best Practice # 2 Version 1.0

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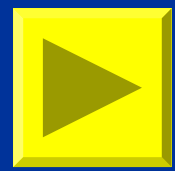
There are two Aspects to this Analysis.

The Qualitative analysis reviews the non-monetary issues of these two Drive Options. To continue with the qualitative analysis continue show or click button.



The Quantitative analysis provides a complete life cycle analysis for a 5, 10, 12, 15 and/or 18 year life cycle. To view the quantitative analysis click button.

CNG Buffer Panel Design & Maintenance

A Case Study to Improve Maintenance and Safety of a Dispenser Control Panel

Best Practice # 6 Version 1.0

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Case Study – Deficiencies of Old Panel

The old priority fill and sequencing panel included separate lines from each compressor and to each dispenser. While this is a good feature, there were no isolation valves provided on the underground lines. If maintenance was required in the panel, all underground lines had to be completely depressurized. This created a hazard with the release of significant quantities of gas. It prevented station operation during maintenance or repairs.

No isolation valves were provided on underground lines to and from panel

Case Study – Features of New Panel

The new panel was designed to allow easy removal of frequently service items such as actuated valves and check valves.

The valves requiring service are mounted on “U” shaped tube assemblies. This allows for their removal without the need to disassemble adjacent tubing. The tubing in this panel is assembled using compression fittings. It would not have been necessary to use the “U” shaped tube assembly, if zero clearance face seal O-ring fittings had been used.

Case Study – Transit Station CNG Buffer Panel

Buffer Panel Depressurization Procedure

Step 4: Isolate Storage Bottles

If the station is not currently in use, the storage bottles valves should also be closed and locked. If the station is to be operated in bypass mode, these bottles must be left open.

CNG Station Gas Filtration

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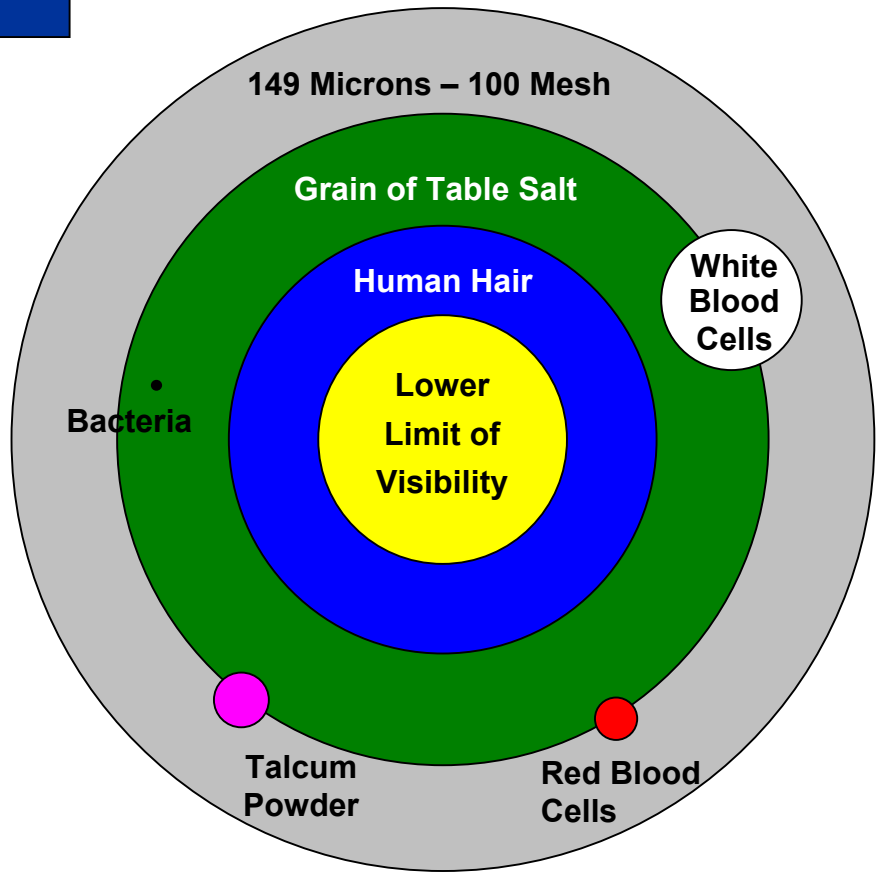
What is a Micron?

A unit of measurement equal to 1 millionth of a meter.

SIZES OF FAMILIAR OBJECTS		
SUBSTANCE	MICRON	INCH
Grain of Table Salt	100	0.004
Human Hair	70	0.0027
Lower Limit of Visibility	40	0.00158
White Blood Cells	25	0.001
Talcum Powder	10	0.0004
Red Blood Cells	8	0.0003
Bacteria	2	0.00008

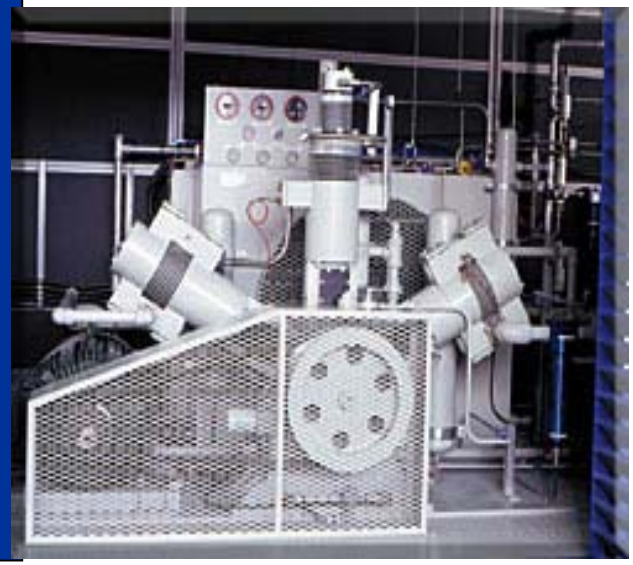


Relative Sizes of Particles & Comparison of Dimensional Units

Compressor Lubrication Types

Non-Lubricated Compressor

A non-lubricated compressor has oil circulated to all moving parts in the crankcase. (See blue arrows on Crosshead Compressor Lubrication slide.) Even though there is no oil intentionally introduced into the gas stream or cylinders, non-lubricated compressors can still experience unintentional oil carryover from the crankcase to the cylinders.



Courtesy IMW Compressors

Mini-Lube Compressor

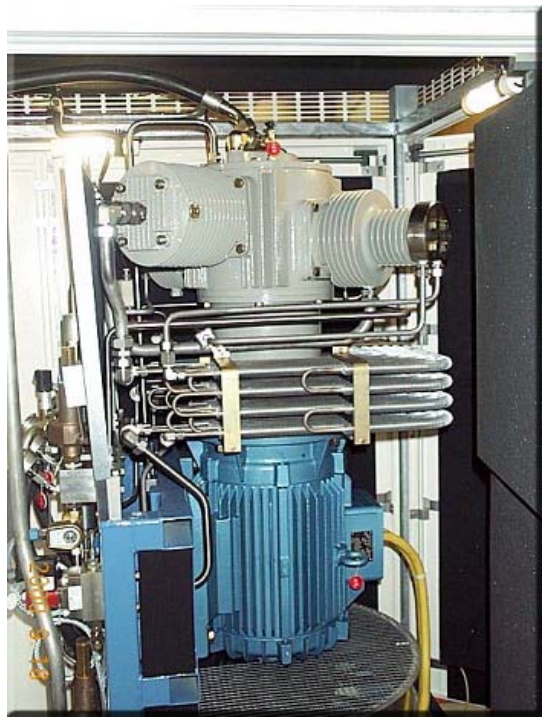
Mini-lube compressors are a hybrid of fully lubricated and non-lubricated compressors. These compressors have full crankcase lubrication systems. Small amounts of oil are injected into the highest pressure stage(s) only.

Compressor Lubrication Types

Oil-Free Compressor

Oil-free compressors have no oil lubrication system in the crankcase or the cylinders. Crankcase moving parts are supplied with pre-lubricated or self lubricated bearings. Rings and valves are provided with self lubricating components. These compressors are usually limited to less than 50 horsepower.

Courtesy FuelMaker



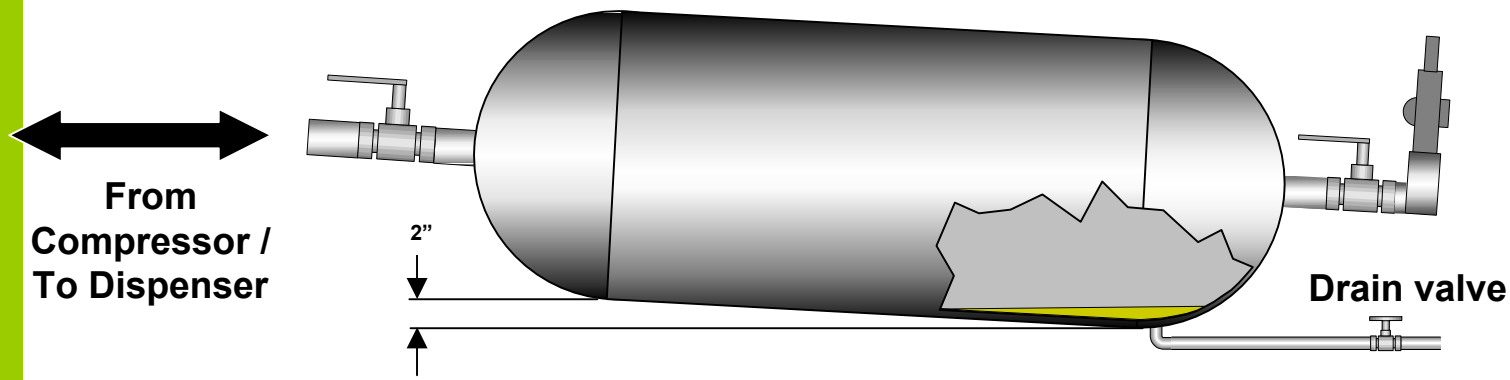
Courtesy Greenfield

Typical Storage Designs

Storage Vessel Installation

CNG storage can be used as another point of condensate removal in the system. When the gas becomes static in the storage, Aerosol that was buoyant in the gas stream may fall out. As the gas cools in the storage, some of the oil vapor may also condense.

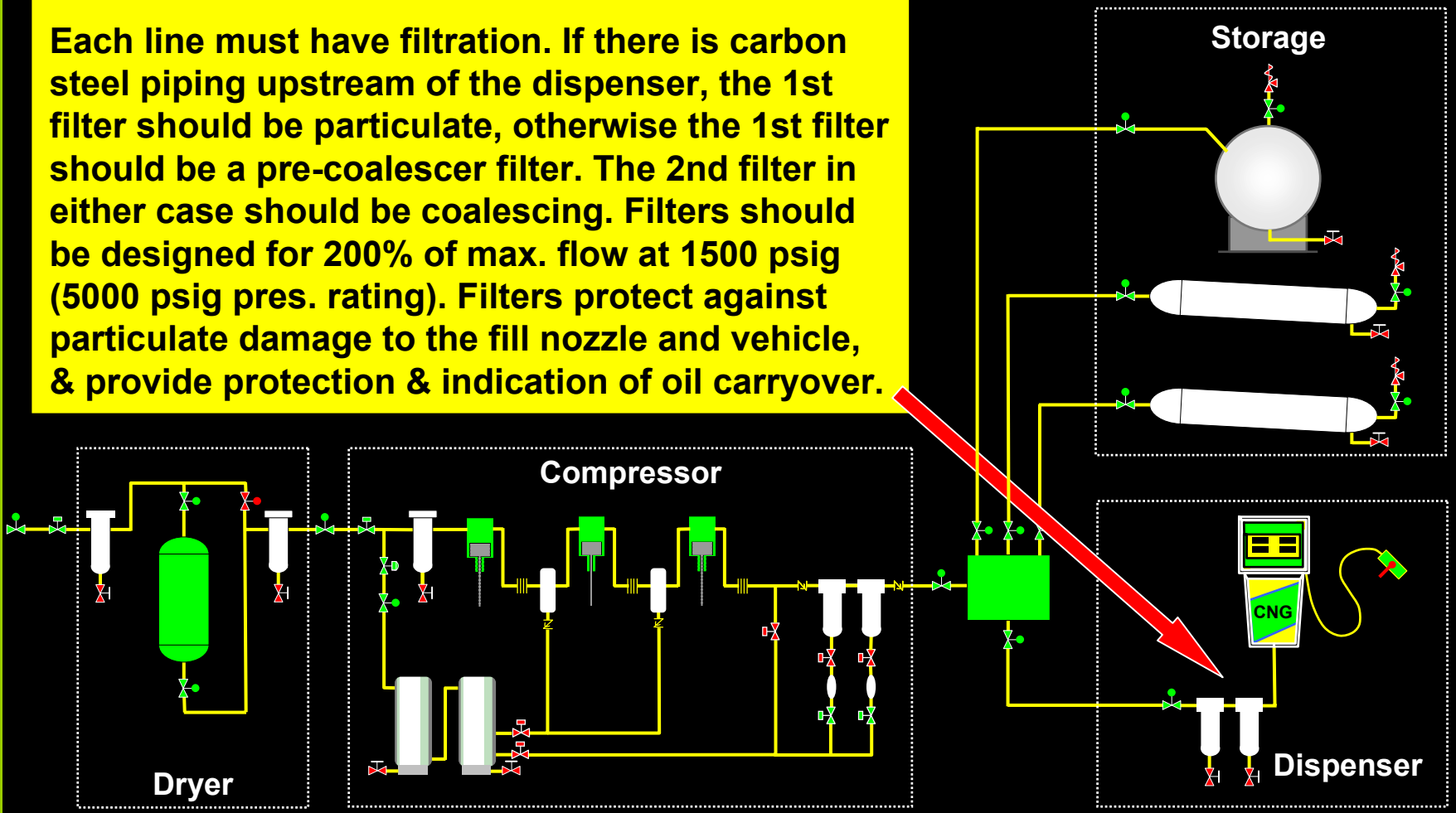
Cylindrical storage vessels should be installed with a slight slope away from the process connection end. This slope will help any condensed oil to puddle away from the flow. A manual drain valve should be installed at the low end of the cylinder. This drain valve must be a multi turn needle or raising plug style valve to ensure safe draining.



Filtration Best Practices

Dispenser Filtration System

Each line must have filtration. If there is carbon steel piping upstream of the dispenser, the 1st filter should be particulate, otherwise the 1st filter should be a pre-coalescer filter. The 2nd filter in either case should be coalescing. Filters should be designed for 200% of max. flow at 1500 psig (5000 psig pres. rating). Filters protect against particulate damage to the fill nozzle and vehicle, & provide protection & indication of oil carryover.



CNG Station Safety

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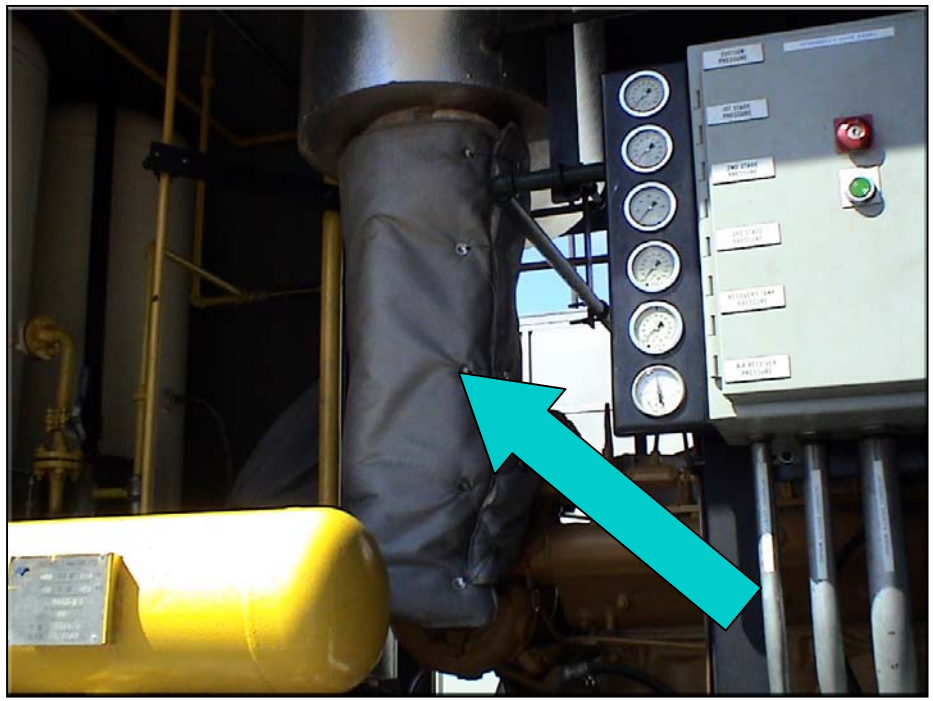
CNG Equipment Protective Devices

Engine exhaust systems can produce temperatures in excess of 1000 ºF. These high temperatures can, under certain circumstances, be hot enough to ignite natural gas. These exhaust systems must be covered with a high temperature insulating blanket or other high temperature insulation to minimize this risk.

Providing a manually activated fan purge for the compressor enclosure helps reduce the risk of a gas build up during maintenance or repair.

This engine exhaust insulation will also reduce the risk of a serious burn to the operator or maintenance personnel.



Engine Exhaust Insulation

CNG Equipment Safety Procedure

Isolate the compressor from all sources of natural gas. This will typically include a suction line and one or more discharge lines. Close off each isolation valve and lock it with an approved device.

Suction Valve

Discharge Valve

CNG Equipment Safety Procedure

Valve Replacement

After maintenance is complete, reinstall the valve into the compressor, making sure that it is in the correct location and orientation. Torque all bolts to the manufacturer's specification using a crisscross pattern as shown.

We wish to thank

GTI / IWG / DOE

and the

Transit Users Group